METEOROLOGY AND THE NATIONAL WELFARE

By ALEXANDER McADIE

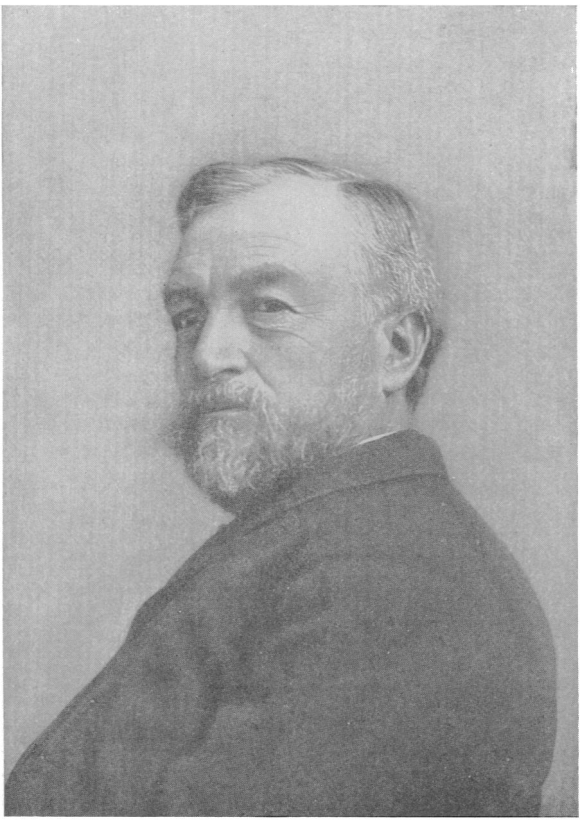
A. LAWRENCE ROTCH PROFESSOR OF METEOROLOGY, HARVARD UNIVERSITY

THERE are some who maintain with cheerful optimism that a stirring of the pool is beneficial for nations as well as individuals. For there seem to be results which the untroubled waters never give. In the present world-wide war surely we have had a stirring sufficiently vigorous to satisfy all anticipations, and it only remains to look for the great good which should follow according to the premise. Certainly there have been great economic, social and political consequences. Among others we may cite the limitation in the use of vodka in Russia, the restricted use of liquors and stimulants in general, the suspension of distillation of spirituous beverages in the United States, the regeneration of Russia politically, the spread of democratic ideas, the exploitation of Africa, the development of under-sea craft and submersibles, and standing out most conspicuous of all, in meteorology, the conquest of the air. Without question the great war has given a stimulus to the art of flight and the construction of air-runners which twenty years of peace might not have equalled. There is no doubt now in the mind of the public as to the future use of the air in the transportation of mail and fast freight. And this present mastery of the air, the medium in which we move, is the greatest advance yet made in the long campaign in which men have sought to rise from earth and rival the birds.

Twenty centuries have passed since men began to speculate concerning the nature of air. Practically there was no advance until a Florentine experimenter (he had had the benefit of a few months' acquaintance with Galileo) turned a tube of mercury upside down in a bowl of mercury. That simple experiment demonstrated that a balance could be maintained between the column of mercury *in vacuo* and something outside, that something being the atmosphere. The master himself died without comprehending the law of aerostatic pressure. It seems simple enough now and every schoolboy understands it, but previous to the middle of the seventeenth century no one knew that human beings walk around at the bottom of a sea of

air which presses upon every square centimeter of their bodies with a force equivalent to 34.5 grams, or if we can not free ourselves from the old English units, with a force equivalent to 14.7 pounds per square inch. It required the composite genius of Torricelli the Florentine, Pascal the Parisian, von Guericke the burgomaster of Magdeburg, and Boyle the Dorsetshire squire, to make plain to men this simplest of facts, namely, that the air in which we move and live and have our being is a physical substance which can be weighed and compressed. It was not until the latter part of the eighteenth century that Cavendish, the most solitary figure in science, announced the chemical composition of atmospheric air. But not until the first decade of our own, the twentieth century, did it occur to men to make use of the inertia of the air. And this, Professor Langley and the Wright brothers did.

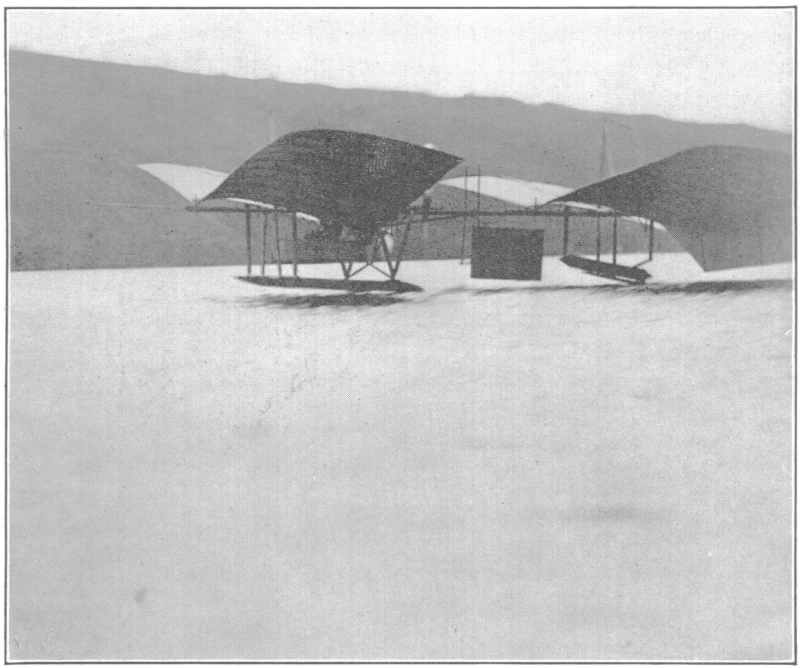
The airplane is simply a skimming plane taking advantage



PROFESSOR S. P. LANGLEY

of the inertia of air at rest. But there is also the inertia of air masses in motion and as yet full advantage of this has not been taken. In the mass motion of air there is a vast store of energy as yet not utilized by man.

Strangely enough, nature did not provide man with any special sense organism whereby changes in air motion could be instantly detected. He only realizes changes due to pressure, when he climbs or is carried to a great height. As for temperature, the average man thinks he is responsive, but in reality always confuses the effects of heat and humidity.



LANGLEY AERODROME IN FLIGHT OVER LAKE KENKA, JUNE 2, 1914

As for changes in the density of the air, or in its ionization, or electrification and nucleation, mankind is as yet hopelessly in the dark. A few laboratory experiments made with apparatus of great sensitiveness mark the boundaries of all that vast unknown. At present we can only wonder and wait. Even in so near a matter as the changes in the internal energy of a mass of water vapor we are sadly handicapped. We are not in any way directly cognizant of the processes of cloudy condensation. Perhaps if we were we could tell in advance weather changes and say with some certainty when the rain would begin and end. We ought to be able to do these things, and yet even official

weather forecasters fall far short of accuracy and, indeed, as the writer has elsewhere said, at present it is the valor of the forecaster rather than the value of the forecast which should be commended.

Leaving these infinitely small excursions and the consequences which follow molecular changes, let us consider briefly the movement of air in bulk or the flow commonly called wind. Watching the motes rise and fall in a dusty atmosphere illuminated by a sunbeam, we have all of us tried to puzzle out the causes of the circulation. It seems as if there were neither regularity nor order in the scurrying of the motes, and yet we know that the circulation must depend upon convectional currents and heat difference. Similarly, in plotting the winds of the globe, which at first glance seem to be equally complicated,

PROFESSOR WILLIAM FERREL

one feels that there must be great currents or streams of air due to convection caused by differences in temperature. We do find that there are some great wind systems and the air apparently streams with much steadiness in certain directions. It is not known how early the name Trade was applied to the winds of tropical latitudes. The navigators of the seventeenth century knew of these steady streams and utilized them in exploration and for commerce. The word "trade" had no reference to commerce, but meant persistence. The northeast Trades were the best known. Halley in 1686, Hadley in 1735, Maury in 1855 and Ferrel in 1889 tried to explain the origin of these winds. The early explanation that air moving from north to south (the directions being reversed in the southern hemisphere) passed to regions of constantly increasing rotational velocity and so would lag behind and seem to have an east component, that is, flow toward the west, satisfied the navigators of the seventeenth century, but did not appear valid to Halley, who knew of calm belts near the equator, monsoon winds in the Indian Ocean and southwest winds off the coast of Guinea. He thought that the flow westward might be in some way connected with the apparent diurnal movement of the sun from east to west. Hadley saw that if the march of the sun were a true explanation, then air should flow in from all sides toward the equator, and the flow toward the east be as vigorous as in the opposite direction. He set forth the deflection of north and south winds, not understanding that east and west winds could also be deflected. Maury plotted the winds and in the main followed Hadley. Making free use of a symmetrical or balanced circulation, he indicated the winds and pressure belts of the higher latitudes, misleading Ferrel, who laid stress upon the deflective effect of the earth's rotation and the necessary outflow from belts of high pressure in the latitude of 30° North and South, and also certain polar "lows." All the theories rest upon an assumed heating of equatorial parts and a surface flow of air from the poles toward the equator. In return there must be an upper current from the equator poleward. All these meteorologists fell into the very natural error of taking it for granted that warming the surface air necessarily caused uplift and motion. While there may be change in density, it does not follow that there will be change in pressure unless the volume remains constant. The dynamics of air motion is concerned rather with the gravitational fall of a mass of cold air displacing a mass of warm air at a lower level. To further complicate the problem, recent observations as embodied in the

Réseau Mondial for 1911 show that in certain trade-wind latitudes neither the direction nor velocity accords with the hitherto accepted values for such latitudes.

ABBOTT LAWRENCE ROTCH, 1861-1912
FOUNDER OF BLUE HILL OBSERVATORY

But rather more important than the trades, so far as the commerce of the world is concerned, are the prevailing westerlies, as they are called, meaning the flow of surface air from west to east in temperate latitudes. These winds along the California coast are often erroneously called trade winds. There is no satisfactory explanation of these winds. Taken in connection with commerce, crops and transportation they are easily the most important of the planetary circulations, and there can be no doubt but that a fuller knowledge of their origin and action would be of much value in our national welfare. It is already apparent that air routes for mail and fast passenger service must be determined by the frequency, intensity and duration of these great aerial currents.

We pass now from these major to what may be caller minor circulations, and come first to the seasonal phenomena known in general as monsoons. The word monsoon itself is from the

Arabic and means season. In connection with these seasonal air flows, the Indian Weather Service has done some valuable work bearing on the relation of these winds to the rainfalls, harvests, droughts and famines of that country. There are certain monsoonal effects noticeable in our known distribution of rainfall, and perhaps if more attention were given to the study of these influences, the accuracy of the forecasts would be improved.

The one great advance in recent years in connection with abnormal seasons was made by Tiesserenc deBort, while studying certain cold winters in northwestern Europe. He gave the name "grand centers of action" to certain areas of high and low pressure which appeared to form and dissipate slowly. These are now better known as hyperbars and infrabars. Displacements of these semi-permanent areas appear to coincide with abnormal seasons. On the Atlantic coast it has been shown by Fassig, Humphreys and others that the movements of the north Atlantic infrabar and the Bermuda hyperbar agree with abnormal seasons. On the Pacific coasts McAdie and Okada have successfully used the displacements of the Aleutian infrabar and the continental hyperbars, for forecasting. In a recent study of the flow of the surface air on the north Atlantic seaboard the writer has shown, using the records of the Blue Hill Observatory for a period of 31 years, that in a warm winter month there is an increase in the south and southwest winds and conversely in a cold winter month an increase in duration of north and northwest winds amounting to nearly 10 per cent. of a normal circulation. The temperature appears to be directly determined by the surface wind. Now the conditions favoring a cold winter month seem to be synchronous with a displacement eastward of the ocean infrabar. On the other hand, a strengthening of the Bermuda hyperbar is accompanied by the prevalence of southerly wind and higher temperature. Again, the matter of droughts in the spring is of great importance; and we find that a dry period at this time of the year is unmistakably associated with a marked increase in the duration of west and northwest winds. Evidently the inflow of moisture-laden air from the sea is lessened, and as both vertical and horizontal circulations are less vigorous than usual, there is less condensation, fewer clouds and an absence of both rain and snow. During a wet spring the north Atlantic infrabar is apparently displaced westward and the Bermuda hyperbar intensified. The surface flow from south to north is accelerated, the alternation of cyclone and anti-cyclone becomes more fre-

quent and apparently the dynamic compression of the air is more marked than in dry periods. Here then we begin to lay the foundation for accurate seasonal forecasts, a matter of great importance, in connection with crop yields and national prosperity.

We come next to the individual disturbances known as cyclones and anti-cyclones and the special types of tropical origin called hurricanes, typhoons and baguios. The term cyclone was first used by Piddington, who also proposed the term cyclonology for the new science of storm movement. Typhoon is from the Chinese, meaning violent wind, and baguio is from the Philippine town near Manila. The fact that the air flow in storms is

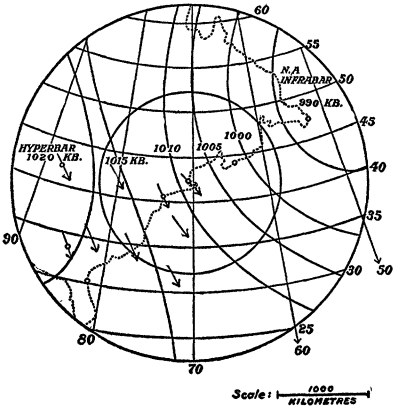


FIG. 1. THE SURFACE AIR FLOW DURING A DRY SPRING. Note: A kilobar (KB) is 1/1000 of a standard atmosphere.

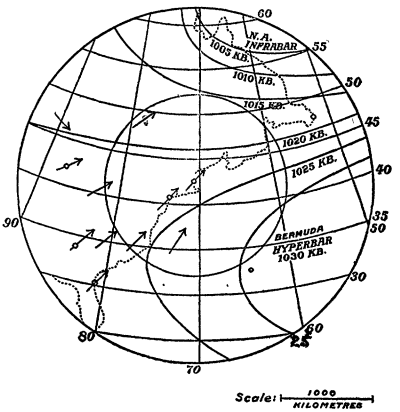


FIG. 2. THE SURFACE AIR FLOW DURING A WET SPRING.

not straight but curved was definitely determined about the middle of the nineteenth century. True there is a paper in the *Philosophical Transactions* for 1698 by Langford describing a West Indian hurricane as a whirlwind and some later references, including one in which Franklin mentions the fact that the air may have traveled many miles in a northeast storm; but it is doubtful if there was any clear concept of the rotational character of a storm at the close of the eighteenth century. Franklin did, however, set forth the fact that storms had a progressive movement, or, in other words, that there was a storm track from Virginia to New England. In a letter to Jared Eliot, July 16, 1747, after describing a wet summer, Franklin says:

We have frequently along this North American Coast storms from

the northeast which flow violently sometimes three or four days. Of these I have had a very singular opinion some years, viz., that though the course of the wind is from the northeast to southwest, yet the course of the storm is from southwest to northeast, that is, the air is in violent commotion in Virginia before it moves in Connecticut and in Connecticut before it moves at Cape Sable, etc.

In another letter to the same correspondent, dated Philadelphia, 13 February, 1750, referring to an eclipse which occurred October 21, 1743, he says:

You desire to know my thoughts about the northwest storms beginning to leeward. Some years since there was an eclipse of the moon at nine o'clock in the evening, which I intended to observe, but before night a storm blew up at northeast and continued violent all night and all next day; the sky thick clouded, dark and rainy so that neither moon nor stars could be seen. The storm did a great deal of damage all along the coast, for we had accounts of it in the newspapers from Boston, Newport, New York, Maryland and Virginia; but what surprised me was to find in the Boston papers an account of an observation of that eclipse made there; for I thought that as the storm was from the northeast it must have begun sooner at Boston that with us, and consequently prevented such observation. I wrote to my brother about it and he informed me that the eclipse was over there an hour before the storm began.

Colonel Capper; Captain Horsburgh; Professor Farrar, of Harvard; W. C. Redfield, a naval architect; Brand, Dove, Reid, Thom, Piddington and Espy established the fact that in the northern hemisphere the motion of rotation was counter clockwise, while in the southern hemisphere it was clockwise. The invention of horn-cards or transparent protractors for anticipating the shift of the wind with the advance of the storm center made it possible for navigators to prepare for the change and take advantage of the shift.

Naturally it was in connection with navigation that this new knowledge found its widest application. Apparently no special use was attempted on land, and as telegraphic communication did not then exist no proposal was made to attempt forecasting. But on the sea it was vital to save ships and many hard and fast rules were laid down for the proper handling of a sailing vessel caught in a rotary storm. As Piddington says:

the navigator was taught first the best chance of avoiding the most violent and dangerous part of a hurricane which is always near the center, next the safest way of managing his vessel, and third the means of profiting by a storm by sailing in a circular course and around, instead of holding to a straight course.

Then came Maury with his "Physical Geography of the Sea." He had the sailor's direct knowledge of the winds.

Graphic indeed are the descriptions of the voyages of the high-masted American clipper ships. The very names tell of the aspiration of their builders. The *Flying Cloud,* the *Archer,* the *Wild Pigeon,* the *Trade Wind,* the *Flying Fish* and the *Glory of the Seas* raced around the world. And our admiration is

DR. JOHN JEFFRIES, OF BOSTON, MASS., FIRST TO TRAVEL BY AIR FROM ONE COUNTRY TO ANOTHER SEPARATED BY THE SEA.

aroused not alone for the clever skippers, but also for the cartographer and investigator whose "Wind and Current Charts" were conned over by these navigators and used to advantage in their struggle for the supremacy of the seas. As illustrating the hydrographer's knowledge of the force, set and direction of the winds and currents of the Atlantic, witness the calculation of the run between New York and the crossing of the equator which vessels of certain rig should make, allowing for adverse winds. The figure given was 4,115 miles. By actual count in two cases the figures came out 4,077 and 4,099. This was the era of our national supremacy on the sea; and Maury's work and wonderful charm of presentation aided in no small degree the attainment of this primacy.

Then came the era of official weather services, inaugurated

in this country by the Signal Corps of the Army. For half a century the work of official weather bureaus has centered in the synoptic map of surface conditions. It is the mainstay of the forecaster and while it has great value, the limit of its possibilities has been reached, for we may say that practically no great improvement has been made in forty years; and the methods of forecasting to-day are essentially the same as when the map was first used. From the very nature of things a map confined to one level can not indicate what is going on in the air at various levels. About fifteen years ago Bigelow attempted the construction of maps at three levels, sea-level, 3,500 feet and 10,000 feet; but the maps as constructed gave rather assumed conditions than the actual state of affairs. It would seem that the closed isobars of the surface open out into loops in the high levels. The temperature distribution, too, is different from that predicated by Ferrel and set forth generally in meteorological text-books. It is far from being a symmetrical distribution. And this in itself upsets the old theory of cyclonic formation and structure. It had indeed been shown from studies of the mean temperatures in anti-cyclones that the old conceptions were faulty. There was need of high-level data and these have been in part supplied by the ascensions of the past ten years, chiefly by kites and sounding balloons and more recently by pilot balloons. A. Lawrence Rotch and Leon Tiesserenc deBort must be regarded as pioneers in the exploration of the upper air. We need not go into detail regarding their work or the more extended efforts of the International Commission for Scientific Aeronautics. The information is given with some detail in an article by Cave in a recent number of the *Quarterly Journal* of the Royal Meteorological Society and also in a book by the writer on Aerography, recently published.

And now we face the era of airplanes through which will come, we hope, the long-desired synchronous survey at various levels. It is evident that what the hydrographer has done for navigation, the aerographer must accomplish for aviation. He takes his place as cartographer and pathfinder of the atmosphere. The logs of the planes will be assembled and the data systematically plotted for the benefit of aerial commerce. And the nation that controls the air, even more than the nation which has supremacy on the sea, will have the command of transportation and communication. It was an American naval officer who brought home to statesmen the influence of sea power upon national destiny. Captain Mahan might modify his views to-day, owing to the advent of aerial fleets, out-speeding, out-

fighting, out-classing the battleships and merchant marine of his time. And our nation has reason to be proud of the important contributions to aerial navigation made by Americans. Maury, Wilkes and Coffin grouped the winds; Rotch issued the first set of charts for aviators and aeronauts, and Dr. John Jeffries was the first to journey by way of the air from one country to another separated by the sea, by a *lighter-than-air* machine, this just one hundred thirty-five years before the era of Zeppelin; and finally Langley, Orville and Wilbur Wright, Maxim, Chanute, Zahn and a host of less well known American engineers, have made flight through the air by *heavier-than-air* machines a matter of daily occurrence. The national air service promises to be the most deadly of the various arms of offense and defense. The air runner is the prospective agency through which all parts of the world shall be made readily accessible. Not only will the now unexplored regions of the earth be mapped, but also the various levels of the atmosphere, particularly in the troposphere, familiarly described as the highways and byways of cloudland. And this new meteorology, airplane meteorology, the science of the structure of the atmosphere, very appropriately carries as its name the significant word, aerography.